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NOTES ON THE FORAMINIFERA OF THE TYPE MERCED AT SEVEN MILE BEACH, SAN MATEO COUNTY, CALIFORNIA

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In 1927 the authors collected thirty-four formation samples from the type section of the Merced series for use in the correlation charts of papers then in preparation on the post-Miocene foraminifera of Humboldt[1] and Ventura counties. At the time there was no thought of getting out a separate paper on the foraminifera from these samples, but later study of the material has made it seem advisable to describe a new *Nonionella* which is rather persistent in the section and to record the other species of foraminifera with which it is here found associated. Such a description and record are the purposes of this paper, which is offered in partial fulfillment of the requirements of work taken at the University of Southern California.

The sampled stations were located with respect to a section paced along the coast between Mussel Rock and the Olympic Club salt water pump house, and additional checks were made with respect to topography. The location of the pump house was obtained through the courtesy of Mr. F. J. Foran of the Olympic Club, Mr. I. E. Flaa of the Spring Valley Water Company and Dr. G. D. Hanna of the California Academy of Sciences.

The type section of the Merced series occurs on the San Francisco Peninsula at Seven Mile Beach, about eight miles south of the Golden Gate. From Mussel Rock, where the basal bed rests unconformably upon the Franciscan, the strata are exposed in ascending sequence to Lake Merced, representing a thickness, as measured by Lawson,[2] of 5834 feet.

This series has quite generally been considered upper Pliocene in age; younger than the Purisima, and perhaps equivalent to the upper part of the Wildcat series of Humboldt County. Evidence to be presented by the authors in a later paper supports this correlation with the upper Wild-

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[1] The Humboldt County work will include a paper now in preparation on the megafossils of the Wildcat series, in addition to those on the foraminifera.

[2] Univ. Calif. Publ. Bull. Dept. Geol., vol. 1, p. 146, 1893.

cat, although it is to be borne in mind that the Wildcat may be somewhat older, as suggested by J. P. Smith,[3] the fauna having migrated southward along the coast.

Several authors[4] have discussed evidence for a division of the series into upper and lower Merced, and for a possible Quaternary age of the upper division. Their point of division in the type section is in the vicinity of Thornton. The data obtained from the few samples considered in this paper are hardly complete enough to justify any definite conclusion regarding such a division, but they suggest that a closer sampling of the section might bring out some very interesting evidence in this regard.

It is worthy of note that more species make either their first or last appearances in the section at the horizon represented by samples 18 and 19 than at any other horizon indicated on Plate 16. Of the twenty-three species and varieties of foraminifera listed, eight make their first appearances and eleven their last appearances in these two samples. Only two of the eight go on up into the section and only five of the eleven go on down, however, the remaining six in each case being confined to one or both of these two samples.

Samples 18 and 19 were taken just north of Thornton from a part of the coastal section which some authors[5] believe to be affected by landslide or faulting. Samples 26 and 27 are from megafossil beds which strike nearly parallel with the shore. Samples 24, 28 and 32 are also from megafossil beds.

Lithologically the Merced is characterized chiefly by soft sandstones and sandy shales. There are occasional beds of very fossiliferous dark clayey mud, and both hard and soft shell beds, as well as thin, hard, unfossiliferous gravel beds occur at intervals. The basal bed, which rests upon the Franciscan at Mussel Rock, is composed almost entirely of plant material, including carbonized wood, bark, matted leaves and pine cones, which, as Lawson[6] has pointed out, is probably an old forest soil representing the land surface just prior to the depression which initiated

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[3] Proc. Calif. Acad. Sci., 4th series, vol. 9, p. 144, 1919.

[4] Among the important references in this connection are: Ashley, G. H., Proc. Calif. Acad. Sci., 2nd series, vol. 5, pp. 318, 330-336, 1895. Arnold, Ralph, U. S. Geol. Survey, Professional Paper no. 47, p. 29, 1906. Lawson, A. C., U. S. Geol. Survey, Geol. Atlas of the U. S., San Francisco Folio, no. 193, p. 14, 1914. Martin, Bruce, Univ. Calif. Publ. Bull. Dept. Geol., vol. 9, pp. 224, 228, 229, 1916.

[5] Op. cit.

[6] U. S. Geol. Survey, Fifteenth Annual Report, p. 460, 1893.

the accumulation of the Merced series. Pine cones, leaves and thin lignitic seams occur here and there, and a thin bed of white volcanic ash has been reported from the upper part of the section.

Martin[7] has expressed the belief that the occurrence of a large number of fossil leaves indicates deposition in an estuarine or littoral zone, and Dorf[8] considers the character of the flora suggestive of coastal conditions of deposition at the mouths of streams. J. P. Smith,[9] basing his conclusions upon invertebrate megafaunal evidence, has stated that the temperature of the sea in which the Merced beds were laid down was probably about 50° F., instead of 55° F. as at present. He considers this megafauna more northern in character than that of the underlying Purisima, agreeing more nearly in character with that of the older and more northerly Wildcat formation. M. L. Natland,[10] judging from a study which he is now making of Recent foraminifera from a section dredged between Long Beach, California, and Catalina Island, believes that the microfauna listed in this paper indicates deposition at depths around 100 to 150 feet. The temperatures which he finds at these depths off Long Beach range around 55° to 58° F. The 50° F. temperature is encountered somewhere around 250 or 300 feet. The surface temperature is about 62° F., some 7° F. higher than that prevailing off San Francisco at present and 12° F. higher than that postulated by Smith for Merced time. It may be that temperature rather than depth is the main controlling factor in the distribution of the species of foraminifera found in the Merced. If so, and if Smith's temperature estimate is correct, these species must have been forced to very shallow depths off San Francisco during Merced time to find temperatures even approximating those at which Natland now finds them off Long Beach.

The authors are indebted to Dr. Joseph A. Cushman, Director of the Cushman Laboratory for Foraminiferal Research, Sharon, Massachusetts, for checking the material used in this paper and for identifying some of the species listed. Data on ocean temperatures were obtained through courtesy of Dr. U. S. Grant, IV and Mr. Clinton G. Abbott of the San Diego Society of Natural History, Dr. T. Wayland Vaughan and Dr.

7 Univ. Calif. Publ. Bull. Dept. Geol., vol. 9, p. 227, 1916.

8 Carnegie Inst. Wash. Publ. No. 412, p. 45, 1930.

9 Proc. Calif. Acad. Sci., 4th series, vol. 9, p. 144, 1919.

10 Oral communication.

Stanley Wilfred Chambers of the Scripps Institution of Oceanography and Mr. M. L. Natland of Long Beach, California.

The contour map of Plate 16 is adapted from a part of the San Mateo Quadrangle of the United States Geological Survey's topographic maps. The locations of the San Andreas Fault and of the northern and southern limits of the Merced series are adapted from Lawson's map in the San Francisco Folio of the United States Geological Survey's Geological Atlas of the United States.

Description of the New Species

Nonionella cushmani R. E. & K. C. Stewart, n. sp.

Plate 17, figures 1a-c

Test subtrochoid, small, strongly oblique in edge view, dorsal side only partially involute, ventral side completely involute; periphery rounded, but not broadly so except in the later chambers of some adult specimens; earlier chambers usually indistinct, later ones distinct, 11 or 12 in the last formed whorl, umbilicus closed by the extended umbilical ends of the last few chambers upon which a small fistulose growth is developed; apertural face nearly flat in side view and with a slightly raised edge; sutures obliquely curved, indistinct in young specimens but becoming more distinct and somewhat depressed between the later chambers of adult specimens; wall calcareous, smooth, finely perforate; aperture narrow and elongate, at the base of the ventral side of the last septal face. Dimensions of holotype: long diameter 0.46 mm., short diameter 0.33 mm., thickness 0.19 mm.

Holotype (Cushman Coll. No. 16408) and paratypes (Stewart Coll. No. 519, Cushman Coll. No. 16409, San Diego Society of Natural History Coll. No. 421, University of Southern California. Coll. No. S. C. M. Mr. 100, University of Chicago, Walker Museum Coll. No. 37398), from sample locality No. 19 of the type Merced at Seven Mile Beach as shown in Plate 16.

The species is named for Dr. Joseph A. Cushman of Sharon, Massachusetts.

It is rather close in some respects to a form referred by Cushman and Kellett[11] to *Nonionella auris* (d'Orbigny). It has no greatly enlarged ventral portion at the umbilical end of the chambers like *N. auris,* how-

[11] Proc. U. S. Nat. Mus., vol. 75, Art. 25, p. 5, pl. 1, figs. 9a-c, pl. 2, figs. 2a-c, 1929.

ever, and the apertural face is nearly flat in side view and has a slightly raised edge, while that of *N. auris* is decidedly convex with no angle. *N. cushmani* in edge view is nearly always oblique, a feature which distinguishes it from most of the other known species of the genus.

In the material studied for this paper, this species occurs only in samples from the lower part of the section, up to and including sample 20.

LIST OF FORAMINIFERA FOUND ASSOCIATED WITH NONIONELLA CUSHMANI

A few references are given for each species wherever possible, but no attempt has been made to make the reference list complete.

Quinqueloculina seminula (Linné)

Serpula seminulum Linnaeus, Syst. Nat., ed. 12, 1767, p. 1264.

Quinqueloculina seminula (Linné), Cushman, Florida State Geol. Survey, Bull. 4, 1930, p. 19, pl. 2, figs. 1, 2.

Lagena acuticosta Reuss

Lagena acuticosta Reuss, Sitz. Akad. Wiss. Wien, vol. 44, pt. 1, 1861 (1862), p. 305, pl. 1, fig. 4.—Cushman, Bull. 104, U. S. Nat. Mus., pt. 4, 1923, p. 5, pl. 1, figs. 1-3; Bull. Scripps Instit. Oceanography, Tech. Ser., vol. 1, 1927, p. 146.—Cushman, Stewart and Stewart, Trans. San Diego Soc. Nat. Hist., vol. 6, 1930, p. 57, pl. 3, fig. 10.

Lagena acuticosta Reuss, var.

Plate 17, figure 4

Two specimens of what appears to be a variety of *L. acuticosta* were found in sample 20.

Lagena laevis (Montagu)

Vermiculum laeve Montagu, Test. Brit., 1803, p. 524.

Lagena laevis (Montagu), Cushman, Bull. 104, U. S. Nat. Mus., 1923, p. 29, pl. 5, fig. 3.

Lagena scalariformis (Williamson), var.

Plate 17, figure 5

Entosolenia squamosa (Montagu), var. *scalariformis* Williamson, Rec. Foram. Great Britain, Ray Society, 1858, p. 13, pl. 1, fig. 30.

A single specimen was found in sample 17 which is very close to the form figured by Williamson.

Lagena sp.

Plate 17, figures 2, 3

Two specimens were found, one in sample 19 and one in sample 20, and since they differ somewhat in the number and development of the costae, both are figured.

Nonionella auris (d'Orbigny)

Valvulina auris d'Orbigny, voy. Amér. Mérid., 1839, vol. 5, pt. 5, "Foraminifères," p. 47, pl. 2, figs. 15-17.

Nonionina auris (d'Orbigny), Cushman, Contr. Cushman Lab. Foram. Res., vol. 1, 1926, p. 91, pl. 13, figs. 4a-c.

Nonionella auris (d'Orbigny), Cushman, Florida State Geol. Survey, Bull. 4, 1930, p. 38, pl. 7, figs. 1a-c.

Elphidium hannai Cushman and Grant

Elphidium hannai Cushman and Grant, Trans. San Diego Soc. Nat. Hist., vol. 5, 1927, pp. 77, 78, pl. 8, figs. 1, 2.—Cushman, Stewart and Stewart, Trans. San Diego Soc. Nat. Hist., vol. 6, 1930, p. 62, pl. 3, figs. 16, 17.

Elphidium hughesi Cushman and Grant, var.

Elphidium hughesi Cushman and Grant, Trans. San Diego Soc. Nat. Hist., vol. 5, 1927, pp. 75, 76, pl. 7, figs. 5a, b.

There appears to be no essential difference between this variety and the form found in the upper part of the coastal section of the Wildcat formation of Humboldt County, California.

Elphidium oregonense Cushman and Grant

Elphidium oregonense Cushman and Grant, Trans. San Diego Soc. Nat. Hist., vol. 5, 1927, p. 79, pl. 8, figs. 3a, b.—Cushman, Stewart and Stewart, Trans. San Diego Soc. Nat. Hist., vol. 6, 1930, p. 62, pl. 4, figs. 1, 2.

Buliminella elegantissima (d'Orbigny)

Bulimina elegantissima d'Orbigny, Voy. Amér. Mérid., 1839, vol. 5, pt. 5, "Foraminifères," p. 51, pl. 7, figs. 13, 14.

Buliminella elegantissima (d'Orbigny), Cushman, Bull. 71, U. S. Nat. Mus., pt. 2, 1911, p. 89; Contr. Cushman Lab. Foram. Res., vol. 1, 1925, p. 40, pl. 6, figs. 5a, b.—Cushman, Stewart and Stewart, Trans. San Diego Soc. Nat. Hist., vol. 6, 1930, p. 64, pl. 4, figs. 7a, b.

Bolivina sp.

A single specimen was found in sample 19 which is too poorly preserved for specific identification.

Eponides ornata (d'Orbigny)

Rosalina ornata d'Orbigny, Voy. Amér. Mérid., 1839, vol. 5, pt. 5, "Foraminifères," p. 42, pl. 1, figs. 18-20.

Eponides ornata (d'Orbigny), Cushman, Stewart and Stewart, Trans. San Diego Soc. Nat. Hist., vol. 6, 1930, p. 72, pl. 6, figs. 2a-c.

Pulvinulinella pacifica Cushman

Pulvinulinella pacifica Cushman, Bull. Scripps Instit. Oceanography, Tech. Ser., vol. 1, 1927, p. 165, pl. 5, figs. 14, 15.—Cushman, Stewart and Stewart, Trans. San Diego Soc. Nat. Hist., vol. 6, 1930, p. 73, pl. 6, figs. 5a-c.

Cassidulina cf. **californica** Cushman and Hughes (?)

Cassidulina californica Cushman and Hughes, Contr. Cushman Lab. Foram. Res., vol. 1, 1925, p. 12, pl. 2, fig. 1.—Cushman, Stewart and Stewart, Trans. San Diego Soc. Nat. Hist., vol. 6, 1930, p. 75, pl. 6, figs. 8a, b.

Only two very small specimens were found which might possibly be referred to this species.

Cassidulina cf. **crassa** d'Orbigny

Cassidulina crassa d'Orbigny, Voy. Amér. Mérid., 1839, vol. 5, pt. 5, "Foraminifères," p. 56, pl. 7, figs. 18-20.—Cushman, Florida State Geol. Survey, Bull. 4, 1930, p. 58, pl. 11, figs. 6a, b.

A few specimens were found in samples 7 and 13 which seem very close to this species.

Cassidulina cf. **limbata** Cushman and Hughes

Cassidulina limbata Cushman and Hughes, Contr. Cushman Lab. Foram. Res., vol. 1, 1925, p. 12, pl. 2, figs. 2a-c.—Cushman, Bull. Scripps Instit. Oceanography, Tech. Ser., vol. 1, 1927, p. 166, pl. 6, fig. 4.

Only four specimens were found in samples 20 and 28, and all but one of them were broken. The identification is considered questionable.

Globigerina conglomerata Schwager

Globigerina conglomerata Schwager, *Novara*-Expd., Geol. Theil., pt. 2, 1866, p. 255, pl. 7, fig. 113.—Cushman and Wickenden, Proc. U. S. Nat. Mus., vol. 75, Art. 9, 1929, p. 12, pl. 5, figs. 6a-c.

Globigerina cf. **conglomerata** Schwager

A number of specimens were found which appear close to this species but do not show the characters clearly enough to be identified with certainty.

Globigerina sp.

This form is too small and represented by an insufficient number of specimens for specific identification.

Cibicides lobatulus (Walker and Jacob)

Nautilus lobatulus Walker and Jacob, Adam's Essays Micros., Kannmacher's ed., 1798, p. 642, pl. 14, fig. 36.

Cibicides sp.

The specimens of this form are too rare and poorly preserved to justify specific identification.